PROJECT SCOPE (WBS 1)

The construction of the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory has been authorized and the funding approved by the United States Congress for a Project Start in fiscal year 1991. This new research facility will meet the highest-priority needs of the U.S. nuclear physics program.

The research objectives of RHIC involve the study of collisions of heavy ion beams (e.g., beams of the nuclei of gold atoms) at energies which range up to 100 GeV/u. In such collisions whose center-of-mass energies exceed the capacity of any existing accelerator of nuclear beams by more than one order of magnitude, experimenters will study extended volumes of nuclear matter with energy densities greater than 10 times that of the nuclear ground state. In this study, an observation will be made of physical phenomena under conditions of temperature and matter density which are believed to have prevailed during the first few microseconds after the origin of the universe. Under these conditions, nuclear matter is expected to lose its identity as a assemblage of neutrons and protons and is predicted to undergo a phase transition to a plasma of quarks and gluons.

The existence and properties of this new state of matter are predicted by quantum chromodynamics (QCD), the theory of the strong nuclear interaction which has been developed over the past two decades of progress and discovery in high energy and nuclear physics. Experiments at RHIC will be designed to carry out a wide-ranging program of measurements to detect and analyze the spectrum of particles radiating from this hot, dense nuclear matter, and to isolate and study the new states of matter thus created. RHIC will be a facility unique in the world. The RHIC research program will enable the U.S. to maintain its prominence in this important area of nuclear science and will sustain Brookhaven National Laboratory as one of the important scientific centers in the world.

The scope of the RHIC Project is to design, construct, and bring into operation a colliding beam facility which will enable studies of nuclear phenomena in relativistic energy heavy ion collisions. The collider, which consists of two concentric rings of superconducting magnets, will be constructed in an existing ring tunnel of ~3.8 km circumference located in the northwest section of the BNL site. The collider is to be able to accelerate and store counterrotating beams of ions ranging from those of gold to hydrogen (proton) at the top energy of 100 GeV/u for gold and 250 GeV for proton. The stored beam lifetime for gold in the energy range of 30 to 100 GeV/u is expected to be approximately 10 hours. The layout of the tunnel and the magnet lattice configuration adopted allow two rings to intersect at six locations along their circumference where the counterrotating beams can be brought to collide with each other.

An existing chain of accelerators, i.e., Tandem Van de Graaff, Booster Synchrotron, and Alternating Gradient Synchrotron (AGS) will be used to pre-accelerate ions for injection into the collider. The scope of the Project, therefore, includes construction of the beam transfer lines from the AGS to the collider. In addition, an initial complement of detectors to exploit RHIC's physics potential will be built as part of this Project.

The Design Manual covers technical areas which are related to the beam transfer lines and the collider. The following sections address performance objectives of the collider, the overview on the collider rings, and the collider operational scenario. Although they are outside of the scope of the present project, discussions on potential future improvements will be given in the last section of this chapter.

Performance Objectives

The performance objectives for a heavy-ion collider were originally formulated in 1983 by a *Task Force for Relativistic Heavy Ion Physics*. The project scope for RHIC as presently defined was finalized with input from scientific and technical review committees and has been endorsed by the DOE/NSF Nuclear Science Advisory Committee in its December 1989 Long Range Plan for Nuclear Science.

The major RHIC performance parameters are summarized in Table 1. These parameters are chosen to satisfy the requirements of the anticipated experimental program which have been stated as follows:

Energy. The top kinetic energy will be 100×100 GeV/u for gold ions. At a Bñ = 839.5 T·m of the magnet system set for 100 GeV/u Au beams, the operational momentum increases with the charge-to-mass ratio, resulting in kinetic energies of 125 GeV/u for lighter ions and 250 GeV for protons. The collider will be able to operate over a wide range from injection to top energies. In order to limit magnet aperture, and thus cost, full luminosity and lifetime requirements are specified at energies above 30×30 GeV/u.

Luminosity. The collider is designed for a Au-Au luminosity of about 2×10^{26} cm^{-2} sec^{-1} at top energy, while maintaining the potential for future upgrades by an order of magnitude. Operation with the heaviest ions imposes the most demanding requirements on the collider design, and gold-on-gold is taken as the prototypical example. The luminosity is energy dependent and decreases in first approximation proportional to the operating energy. The luminosity for lighter ions will be higher, with ~1×10^{31} cm^{-2} sec^{-1} for pp collisions.

Range of ion masses. The expectations for interesting physics phenomena require a broad range of nuclei from the heaviest to the lightest, including protons. Asymmetric operation with heavy ions colliding on protons is considered to be crucial for the experimental program. The collider will allow collisions of beams of equal ion species from Au-Au all the way down to p-p. It will also allow operation of unequal species such as protons on gold ions.

Uranium is a viable species and can be considered as a future upgrade. However, at the present, an adequate source for uranium does not exist at Brookhaven and further R&D will be needed to achieve this goal.

Intersection Regions. The existing tunnel and the magnet lattice configuration provides for six experimental areas where the circulating beams cross. Three of the experimental areas presently have completed experimental halls with a support building for utilities: Narrow Angle Hall, Wide Angle Hall and Major Facility Hall. Another experimental area is an "Open Area" complete with support building and is suitable for small experiments.

A warm space of about ±9 m at each crossing point is provided for the experimental detectors, with a free space of ±7.12 m space available for the experimental beam pipes. The crossing point configuration foresees head-on collisions, but allows crossing angles up to 1.7 mrad.

For head-on collisions, the interaction region length will be a nominal 18 cm rms over 10 hours at all energies.

Table 1. RHIC Performance Objectives

No. Intersection Regions	6
No. Bunches/ring	60
Bunch Spacing (nsec)	213
Collision Angle	0
Free Space at Crossing Point (m)	±9

	Au	p
No. Particles/Bunch	1×10^{9}	1×10^{11}
Top Energy (GeV/u)	100	250
Emittance, initial (ð mm.mrad)	10	20
Diamond Length (cm rms)	18	10
Beta* (m)	2	2
Luminosity, average (cm^{-2} sec^{-1})	~ 2×10^{26}	~ 1×10^{31}
Lifetime (h)	~ 10	> 10

The beta function at each crossing point is continuously adjustable from â* = 10 m down to 2 m (and possibly to 1 m) by changing the currents in the insertion quadrupoles. Injection, acceleration and operation at 30 GeV/u requires the â* = 10 m setting. The low-beta setting can be activated at top energy.

The paramount design features of RHIC, which will ensure that its performance objectives can be achieved, are summarized in the subsequent sections of the *Project Scope*.